Space I

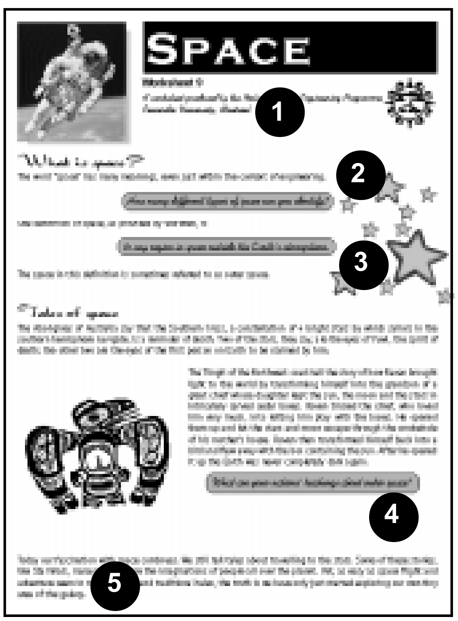
Worksheet 9

A worksheet produced by the Native Access to Engineering Programme
Concordia University, Montreal

Teacher's Guide

Here are some suggestions for how can work with Worksheet 9, Space.

1. There is a wealth of information available to educators regarding space, space exploration, space science etc. This worksheet only touches on some very basic, introductory ideas. If your students are really interested in the subject let them explore the Internet at will; the URLs at the end of the worksheet are good places to start. NASA, in particular, has a tremendous amount of well designed and interesting information and activities designed for students K-12. In addition to online sources you can contact the following institutions for materials regarding space.



The Canadian Space Agency
6767 route de l' Aéroport
Saint-Hubert, QC J3Y 8Y9
Tel: 450-926-4351
URL: www.space.gc.ca

The Edmonton Space and Science Centre
11211-142 Street
Edmonton, AB T5M 4A1
Tel: 780-451-3344
URL: www.edmontonscience.com

Pacific Space Centre
1100 Chestnut
Vancouver, BC V6J 3J9
Tel: 604-738-7827
URL: pacific-space-centre.bc.ca

Cosmodome/Space Camp Canada
2150 Autoroute des Laurentides
Laval, QC H7T 2T8
Tel: 450-978-3615
URL: www.cosmodome.org

The Ontario Science Centre
770 Don Mills Road
North York, ON M3C 1T3
Tel: 416-696-3140
URL: www.osc.on.ca

There is also a Canadian Space Resource Centre (CSRC) serving each region of the country. These centres are set up specifically to help educators and the public find materials relating to space.

Atlantic
CSRC
Discovery Centre
1593 Barrington Street
Halifax, NS B3J 1Z7
Tel: 902-492-4422
URL: www.discoverycentre.ns.ca

British Columbia, Northwest Territories and the Yukon
CSRC is at the Pacific Science Centre
Tel: 604-738-7827 ext. 231 or
1-800-551-3500

Ontario
CSRC
Marc Garneau Collegiate Institute
135 Overlea Boulevard
East York, ON M3C 1B3
Tel: 416-396-2421
URL: www.spacenet.eybe.edu.ca

Prairies
CSRC
Western Space Education Network
2115 McKeown Avenue
PO Box 1811
Saskatoon, SK S7K 3S2
Tel: 306-374-1395
URL: www.scs.sk.ca/wse/default.htm

Quebec and Nunavut
CSRC is at the Cosmodome
Tel: 450-978-3602

2. Space can be:
   - an area within a building reserved for a particular use, like library space or class room space;
   - an empty area between two objects, such as the space between a maglev train and its rails, or the space between two buildings;
   - more generally, it can be any defined three-dimensional volume.

   Your students may come up with any number of different examples.

3. Do your students understand the definition? Can they place it within the context of a sentence?

4. The answer to this question will vary according to class, community and nation. According to the *Aboriginal Astronomy Project* (www.schoolnet.ca/aboriginal/science/astronom-e.htm), "Many Aboriginal cultures describe space travel. Some cultures maintain oral traditions which confirm that humans traveled to distant stars well before modern rocket science enabled space exploration …" Certain stars, planets and astronomical phenomena have also played roles in the histories of certain nations. Perhaps an Elder could be invited to discuss with the class your nation's teachings. Stories from a number of different nations can be found at *Starlore of the American Indian*, www.ac.wwu.edu/~skywise/legends.html.

5. Space, the vast region beyond our planet, has been a great unknown for most of our existence and yet it has captured our imaginations since the beginning of time. The night sky can literally put on the greatest show on (or off) Earth. The rising and setting of the sun, the cycles of the moon, seasonal meteor showers, planetary movements, the constellations, northern lights, comets and supernovae; ancient peoples observed all of these phenomena, just as we do today. And, just as we do, they searched for ways to explain what they saw.

   Having students reflect on our fascination with space may make an interesting class discussion or essay topic.

6. The gravity of a planet can capture space borne objects – such as meteors, and drag them into the planet's atmosphere. Very strong gravity wells, like black holes can capture anything which strays into their sphere of influence; blackholes are so strong they even capture in light.

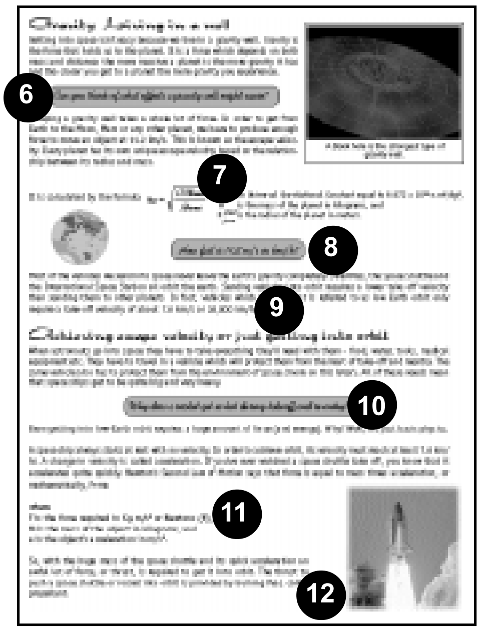
7. Your students can compare the escape velocity for each planet in the Solar System. Have them construct a table as follows and calculate the escape velocities from the given formula. The escape velocities are provided here for your information.

Planet	Radius (m)	Mass (kg)	Escape velocity (m/s)
Mercury	2,439,000	3.3×10^{23}	4,300
Venus	6,052,000	4.87×10^{24}	10,400
Mars	3,394,000	6.42×10^{23}	5,000
Jupiter	71,400,000	1.9×10^{27}	59,500
Saturn	60,300,000	5.69×10^{26}	35,600
Uranus	25,559,000	8.68×10^{25}	21,300
Neptune	24,764,000	1.02×10^{26}	23,300
Pluto	1,150,000	1.29×10^{22}	1,100

This information was obtained from Welcome to the Planets, www.pds.jpl.nasa.gov/planets

What planet has the highest escape velocity? The lowest?

What relationship, if any, do they notice between the mass and radius of a planet with respect to escape velocity?

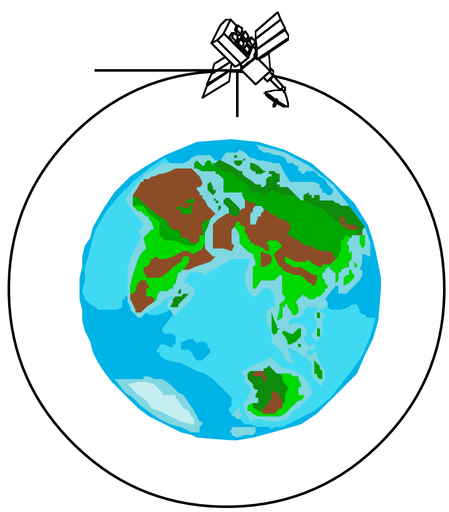


8. This is a units conversion exercise.

$$11.2\frac{km}{s} x60 \frac{s}{m} x60 \frac{m}{h} = 40,320 \frac{km}{h}$$

9. Do your students know what orbit is?

Orbit is a balancing act between the force creating an object's forward motion and the pull of a planet's gravity. If the force of forward motion is large enough to overcome gravity, the object will escape the planet's pull and take off into space. If gravity is large enough to overcome the force of forward motion, the object's orbit will decay and it will fall into the planet's atmosphere.



10. Rockets get very hot during take off and re-entry because of the friction between the surface of the vehicle and the air. Rockets and the space shuttle are covered with special materials which help to dissipate this heat. The heat from air friction affects any object entering or leaving the Earth's atmosphere; it is so hot that it causes most meteors to burn up long before they get near the planet's surface. Shooting stars are actually small meteors which burn up after hitting the Earth's atmosphere.

11. **Exercise:**

How much force is required to get the Space Shuttle into orbit?

The Shuttle, which weighs approximately 9.9 million kg at lift off, goes from 0m/s to 7.8km/s in about 8.5 minutes.

i. We know that F=ma, and that m= 9,900,000kg. So first we have to figure out the shuttle's acceleration.

$$a = \frac{v}{t}$$

ii. Convert km/s to m/s

$$7.8\ \frac{km}{s} \times \frac{1000m}{km} = 7{,}800m/s$$

iii. Convert minutes to seconds

$$8.5m \times \frac{60s}{min} = 510s$$

iv. Calculate acceleration

$$a = \frac{v}{t} = \frac{7{,}800\ m/s}{510\ s} = 15.3\ m/s^2$$

v. Calculate required force

$$F = ma$$
$$= 9{,}900{,}000kg \times 15.3\ m/s^2$$
$$= 151{,}470{,}000N$$

12. The thrust to push a space shuttle or rocket into orbit is provided by burning fuel, called propellant. The propellant may be solid or liquid, or in the case of the Space Shuttle, both. The Space Shuttle has an external tank which holds more than 2 million litres of liquid hydrogen and oxygen which provide the thrust for the shuttles 3 main engines. All of this fuel is used to provide the initial thrust to get the shuttle into orbit. The shuttle also has two solid rocket boosters. Each rocket carries a mixture of chemicals including ammonium perchlorate, aluminum and iron oxide.

When fuel is combusted there are always byproducts. For instance, by products from gasoline include carbon monoxide and carbon dioxide, one of the green house gases. It might be interesting to discuss the byproducts of rocket fuel combustion with your students. For instance can they think of what might be a byproduct of the mixing of hydrogen and oxygen. Water (H_2O) is actually one of the main byproducts of shuttle propellant, it is made when two hydrogen molecules bind with one oxygen molecule.

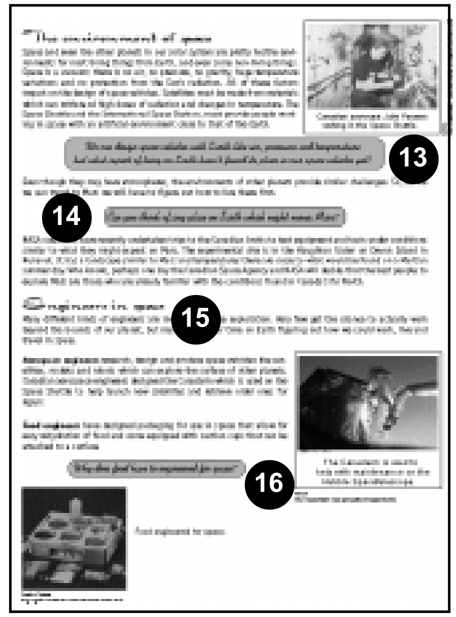
13. We still have not built space vehicles with artificial gravity. Without gravity, astronauts in space have no way to determine what is up, down, left or right which can be disorienting. The lack of gravity also affects the liquid in the inner ear which normally helps us to balance. It is this disturbance in the inner ear coupled with general disorientation which is largely responsible for space sickness. Astronauts who travel in space have to learn to deal with the disorientation.

In training astronauts do many exercises which will help them to deal with the low or no gravity environment of space.

Exercise (from *The Engaging Science Play Book*, ScienceWorld, Vancouver):

Get your students to pair off. One is the pilot, the other is the trainer. The pilot should stand up and look straight up at the ceiling. The trainer now spins the pilot around ten times (slowly). Once the spinning is completed. The trainer should step back one big step (about a meter), and hold out an arm, pointing the index finger towards the pilot. The trainer should then ask the pilot to “Press the emergency button,” the tip of the index finger.

The pilot and trainer should repeat the exercise until the pilot is successful (or until the pilot feels REALLY sick). Have them record the number of attempts it takes for the pilot to succeed. Does it get easier with each try? The students can then switch roles.



14. Land in both the far north, see the paragraph below the question regarding the Arctic, and the far south (Antarctica) mimics some of the conditions found on Mars: the landscape is similar, the extremes in temperature are close to that of Martian summer days. NASA has been favouring sites like Haughton Crater in the Arctic because they are closer to emergency services if any accidents occur during training.

15. If your students are really turned on by space it might make an interesting class research exercise for each of them to look at one aspect of space exploration. You could use the list of engineers below as a starting point, or just have each of them look at some aspect of daily life (eating, sleeping, going to the bathroom) which might be more challenging in space.

16. The food the astronauts take into space has to be engineered for a number of reasons.

- Weight, or lack thereof, is of the essence in space travel. The less the a vehicle weighs, the less it costs to get it into space. Water is pretty heavy, so by dehydrating food money is saved.
- Dehydrated food also requires no refrigeration.
- Space (the kind you work and live in) is also at a premium on any space vehicle; dehydrated food take sup less room.
- Because there is no gravity in space, all food has to be contained in special packaging. It allows for easy rehydration and access but keeps the food from floating away and gumming up air filters etc…
- Some of the food packages also come equipped with their own heating cell so that meals can be heated up without an oven or microwave.
- Medicine and pills are not really food, but they too require special packaging for use in space. Pills are packed in bottles which only dispense one pill at a time – kind of like a Pez dispenser; otherwise an entire bottle of Tylenol could end up floating throughout the cabin.

17. Jerry C. HighEagle was featured in the January 1999 issue of harmonics.

18. When moving in an atmosphere objects are always subject to friction, in a vacuum there is no friction.

19. Structural engineers: With the development of the International space Station we have begun to build things in space. Structural engineers play a role in design and construction of the ISS.

Automotive engineers: When astronauts went to the moon, they had a “car” which they drove over the lunar surface to collect soil and other samples. It was a specialized design made to work in the moon’s environment.

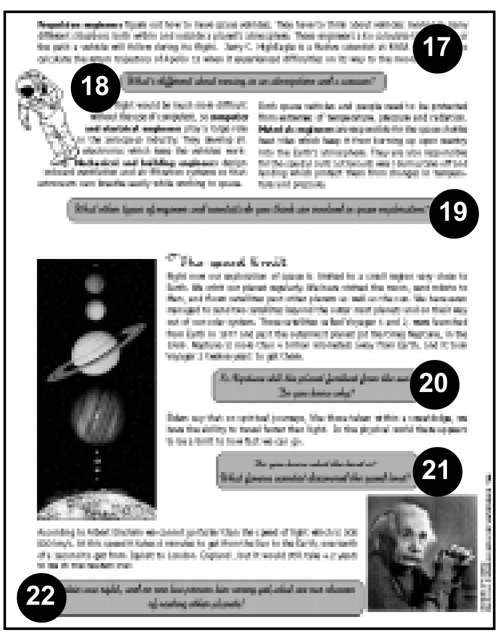
Robotics engineers: More and more planetary exploration is being undertaken by through the use of robotic vehicles, like the Mars Rover, controlled from Earth. Robotics engineers work to design robots which will be able to navigate awkward terrain and collect data to be sent back to Earth.

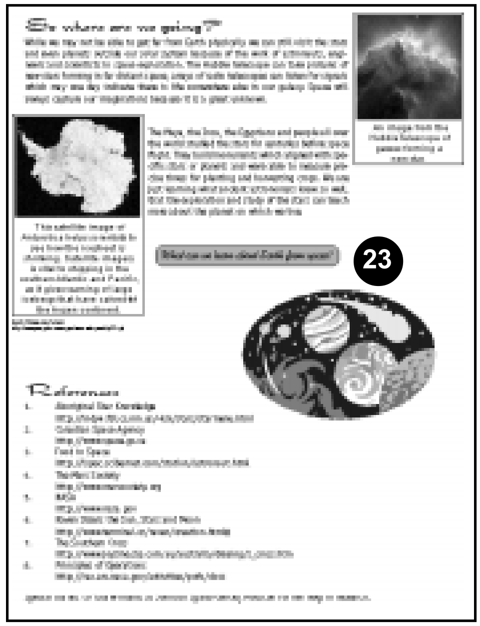
Communications engineers: Satellites, space vehicles and robots on distant planets send their findings back to Earth electronically. Communications engineers make sure that the vehicles have the required communications equipment, and plan for the special mission of these vehicles. Satellites and vehicles which are far away must be able to deal with time lag, from Earth to Mars the time lag in communications is about 6 minutes.

20. Neptune is no longer the planet furthest from the sun, Pluto is. Most of the time Pluto is the solar system’s most remote planet, but it has an orbit which is very eccentric and more elliptical than that of the other planets. Occasionally this eccentric orbit brings it closer to the sun than Neptune for a period of about 20 years. Pluto regained its title as the remotest planet in 1999.

21. The speed limit is the speed of light or 300,000km/s. Albert Einstein theorized that nothing can go faster than light. His theory of relativity basically says that no matter how fast you are travelling light travels at 300,000km/s relative to you – essentially you can never catch up with it.

22. Barring unforeseen developments in space propulsion and travel, it would take us a very long time to reach other planets outside of our own solar system. Unless we are prepared to build space vehicles which can house and provide for the needs of a number of generations, or devise propulsion systems which can close to the speed of light it is unlikely we will physically travel to other solar systems.



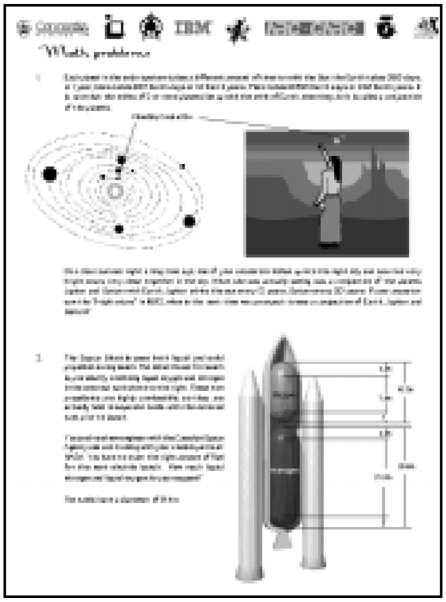


23. From space there is an almost unending list of things we can learn about Earth. The unique viewpoint provided by the altitude of orbiting satellites and space vehicles allows scientists to learn about and study:

- the growth or shrinkage of the polar ozone holes;
- the shrinkage of the polar ice sheets;
- weather phenomena such as hurricanes and El Nino;
- deforestation caused by logging and forest fires;
- ocean currents;
- environmental disasters such as oil spills;
- the migration of refugee populations;
- ancient impact craters from large meteors or asteroids hitting the planet;
- distribution of land use;
- land and ocean temperatures.

A great web site for teachers looking at Earth Science as aided by space exploration is the Earth Observing System, http://eospso.gsfc.nasa.gov/eos_edu.pack

Canada has its own Earth observation satellite called RADARSAT-1 which is operated by the Canadian Space Agency. Launched in 1995, it orbits the Earth at an altitude of 800km. It is used for mapping, environmental change detection and ice and ocean monitoring. More recently it has also been used to help with humanitarian relief in places subjected to natural disasters. By taking images of large land areas, satellite imagery specialists are able to pass on information to relief agencies and other governments which allows for quick and more efficient delivery of food, medicines and supplies to flood or earthquake ravaged areas. More information about RADARSAT is available on the Canadian Space Agency's web site, www.space.gc.ca.



Solutions

Problem 1.: Lowest Common Multiple (LCM)

Your students should be familiar with the method for determining the LCM of 2 or more numbers, but it may have been a while since they have had to draw on such basic math skills. This problem illustrates that even basic math plays an important role in high level science.

I. What do we know?

Orbit of Jupiter: 12 Earth years
Orbit of Saturn: 30 Earth years.
Year of conjunction: 1682

II. Determine the frequency of an Earth-Saturn-Jupiter conjunction.

The frequency of, or interval between, conjunctions of Earth, Saturn and Jupiter can be determined by finding the LCM of 12 and 30. Students should list the multiples of each number (perhaps in a table as below) to determine the LCM.

	12	30
1	12	30
2	24	60
3	36	90
4	48	120
5	60	150

From the table it can be seen that the LCM of 12 and 30 is 60, so an Earth-Saturn-Jupiter conjunction occurs every 60 years.

Alternate method

Another method for calculating the LCM is to express each number in terms of its primary factors.

$12 = 2^2 \times 3$
$30 = 2 \times 3 \times 5$

The LCM is then determined by multiplying all of the primary factors of both numbers, but for each primary factor using only the highest power of the number. For instance if you had a two numbers, one with a primary factor of 3^2 and the other with a primary factor of 3^4, in determining the LCM you would use 3^4. In our exercise this means we use 2^2 to determine the LCM for 12 and 30.

$$\text{LCM} = 2^2 \times 3 \times 5 = 60$$

III. Determine when the next an Earth-Saturn-Jupiter conjunction will occur.

The next conjunction can be determined by adding 60 years to the date of the last known conjunction until a 21st century date appears.

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1682
 + 60
1742
 + 60
1802
 + 60
1862
 + 60
1922
 + 60
1982
 + 60
2042
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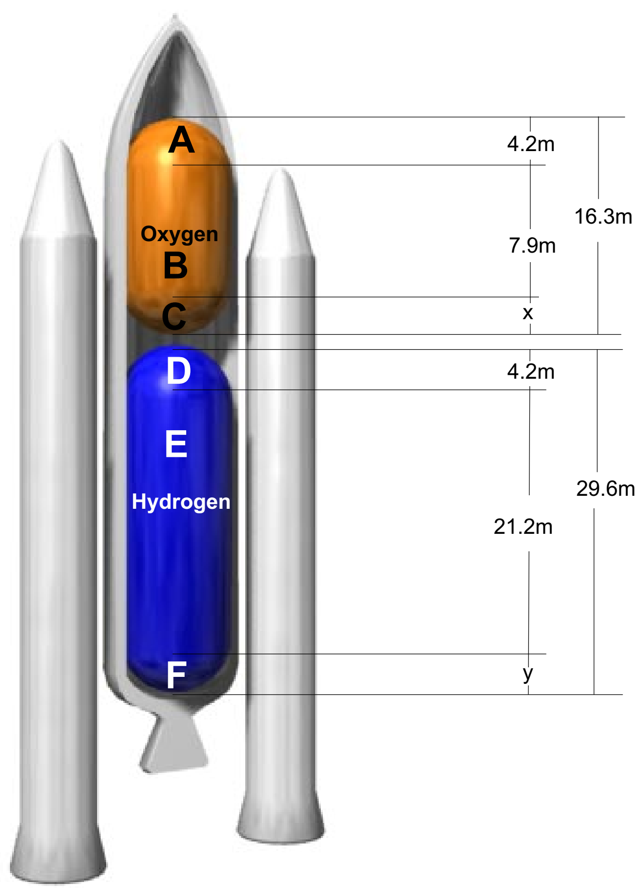
Answer:
The next conjunction of Earth, Saturn and Jupiter will occur in 2042.

Problem 2: Volume

I. What do we know?

Diameter of both tanks: 8.4m
Total length oxygen tank: 16.3m
Total length hydrogen tank: 29.6m

Labeling the tanks as shown we also know that:
Length of sections A and D: 4.2m
Length of section B: 7.9m
Length of section E: 21.2m



II. Determine values for x and y

x

$x + 4.2m + 7.9m = 16.9m$
$x = 16.9m - 4.2m - 7.9m$
$= 4.2m$

y

$y + 4.2m + 21.2m = 29.6m$
$y = 29.6m - 4.2m - 21.2m$
$= 4.2\ m$

III. Determine the volume of section A

Section A has a circular cross section with an 8.4m diameter. It is 4.2m high, or half the diameter (therefore the radius). From the given diagram, we can see that the oxygen tank is rounded at both ends, we can therefore assume that the volume of section A can be approximated by the volume for half a sphere. (Part of engineering is learning how to make appropriate assumptions.)

The volume of a sphere is determined by the formula

$$V = \frac{4}{3}\pi r^3$$

Section A is only half a sphere so

$$V_A = \frac{1}{2}\left(\frac{4}{3}\pi r^3\right)$$

$$= \frac{1}{2}\left(\frac{4}{3}\pi (4.2m)^3\right)$$

$$= 155m^3$$

IV. Determine the volume of sections C, D and F

Sections C, D and F have the same dimensions as section A, there fore their volume will be the same as that of section A.

$V_A = V_C = V_D = V_F = 155m^3$

V. Determine the volume of section B

Section B is a cylinder,

$V_B = \pi r^2 h$

The radius is half the diameter or 4.2m

$V_B = \pi(4.2m)^2 \times 7.9m$

$= 438m^3$

VI. Determine the volume of section E

Section E is also a cylinder and can be determined using the same formula as for section B.

$V_E = \pi(4.2m)^2 \times 21.2m$
$= 1175m^3$

VII. Determine the volume of the oxygen tank.

$V_{oxygen} = V_A + V_B + V_C$

$= 155m^3 + 438m^3 + 155m^3$
$= 748m^3$

VIII. Determine the volume of the hydrogen tank.

$V_{hydrogen} = V_D + V_E + V_F$

$= 155m^3 + 1175m^3 + 155m^3$
$= 1485m^3$

Answer:
You should order 748m³ of liquid oxygen and 1485m³ of liquid hydrogen.

Notes